(51) International Patent Classification⁷: G03F 1/14, 7/20

(21) International Application Number:
PCT/JP2004/009375

(22) International Filing Date: 25 June 2004 (25.06.2004)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
2003-182041   26 June 2003 (26.06.2003)   JP
2004-097699   30 March 2004 (30.03.2004)   JP

(71) Applicant (for all designated States except US): CANON KABUSHIKI KAISHA [JP/JP]; 30-2, Shimomaruko 3-chome, Ohta-ku, Tokyo 146-8501 (JP).

(72) Inventors; and
(75) Inventors/Applicants (for US only): YAMAGUCHI, Takako [JP/JP]; Canon-ryo, 2-10-1, Asahicho, Atsugi-shi, Kanagawa 243-0014 (JP). INAO, Yasuhisa [JP/JP]; Canon-ryo, 2-6-29, Mizuhiki, Atsugi-shi, Kanagawa 243-0004 (JP).

(74) Agent: YAMADA, Ryuichi; TOKO International Patent Office, Hasegawa Bldg. 4F, 7-7, Toranomon 3-chome, Minato-ku, Tokyo 105-0001 (JP).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— with international search report

(54) Title: EXPOSURE MASK, METHOD OF DESIGNING AND MANUFACTURING THE SAME, EXPOSURE METHOD AND APPARATUS, PATTERN FORMING METHOD, AND DEVICE MANUFACTURING METHOD
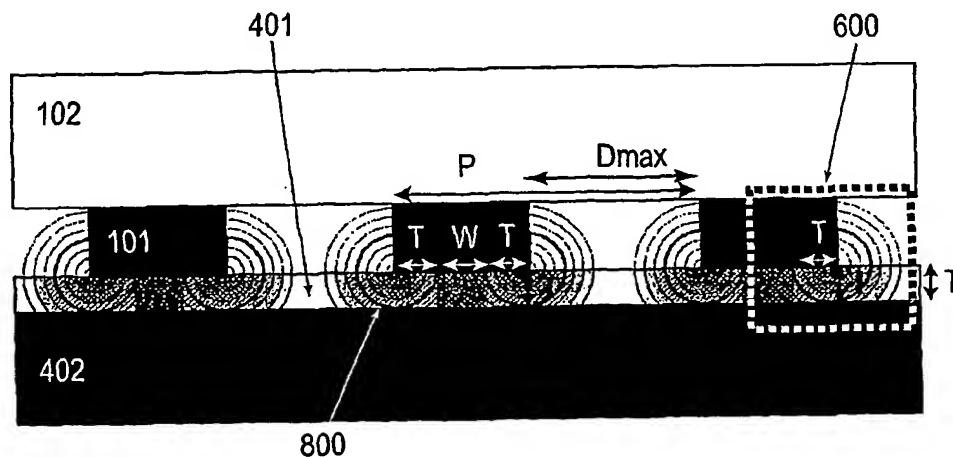
(57) Abstract: This specification discloses an exposure mask, a method of designing and manufacturing an exposure mask, an exposure method and apparatus, a pattern forming method, and a device manufacturing method. Specifically, the exposure mask is adapted to expose an image forming layer provided on a substrate, by use of near field light leaking from adjoining openings formed in a light blocking member, wherein the light blocking film has an opening interval that is determined so that an electric field distribution at the image forming layer side of the opening to be defined as exposure light is projected on the light blocking member has a correlation with an eccentric model of electric field distribution as determined by a linewidth and a height of a pattern to be produced.

DESCRIPTION

EXPOSURE MASK, METHOD OF DESIGNING AND MANUFACTURING THE SAME, EXPOSURE METHOD
5   AND APPARATUS, PATTERN FORMING METHOD, AND DEVICE MANUFACTURING METHOD

[TECHNICAL FIELD]

This invention relates generally to
10   near field exposure technology that enables
production of a fine pattern and, more
particularly, to an exposure mask, a method of
designing and manufacturing an exposure mask, an
exposure method and apparatus, a pattern forming
15   method, and a device manufacturing method, for
example.

[BACKGROUND ART]

Increasing capacity of a semiconductor
20   memory and increasing speed and density of a CPU
processor have inevitably necessitated further
improvements in fineness of microprocessing
through optical lithography. Generally, the limit
of microprocessing with an optical lithographic
25   apparatus is of an order of the wavelength of
light used. Thus, the wavelength of light used in
optical lithographic apparatuses haven been

shortened more and more. Currently, near
ultraviolet laser is used, and microprocessing of
0.1 μm order is enabled. While the fineness is
being improved in the optical lithography, in

5   order to assure microprocessing of 0.1 μm or
narrower, there still remain many unsolved
problems such as further shortening of laser,
development of lenses usable in such wavelength
region, and the like.

10   On the other hand, as a measure for
enabling microprocessing of 0.1 μm or narrower, a
microprocessing apparatus using a structure of a
near-field optical microscope (scanning near-field
optical microscope: SNOM), has been proposed. An

15   example is an exposure apparatus in which, by use
of evanescent light leaking from a fine opening of
a size not greater than 100 nm, local exposure
that exceeds the light wavelength limit is
performed to a resist.

20   However, since such lithographic
apparatus with an SNOM structure is arranged to
execute the microprocessing by use of one or more
processing probes, as like continuous drawing.
Thus, there is a problem that the throughput is

25   not high.

                As one method for solving such problem,
U.S. Patent No. 6,171,730 proposes an exposure

method in which a photomask having a pattern

arranged so that near field light leaks from a

light blocking film, is closely contacted to a

photoresist upon a substrate, whereby a fine

5   pattern of the photomask is transferred to the

photoresist at once.

The method and apparatus disclosed in

the aforementioned U.S. patent is very useful and

it makes a large contribution to the technical

10   field to which the present invention pertains.

Also, Japanese Laid-Open Patent

Application No. 11-317345 and U.S. Patent No.

6,497,996 disclose that such near field light has

a property that the intensity is attenuated as

15   like an exponential function with the distance

from the fine opening and, thus, the film

thickness of a pattern forming layer based on the

near field exposure has to be made thin.

Figure 2 illustrates a near-field

20   electric field distribution around a mask opening

obtained by investigation made through simulations.

Specifically, Figure 2 shows the state of electric

field distribution produced adjacent the opening,

where light of a wavelength 436 nm is projected to

25   a near-field exposure mask having a pitch 200 nm

and a mask opening width of 70 nm. Values in the

drawing are relative electric field intensities at

respective positions where the intensity of
incident light is taken as 1.

Seeing the electric field distribution,
there is extension from the opening to the light
5   blocking film portion. This means that there is a
possibility that the opening pattern of the mask
and the pattern provided by exposure do not
completely correspond to each other.

The feature that the electric field
10   intensity attenuates as coming away from the mask
opening and that there appears an electric field
distribution being extended in a direction
parallel to the mask surface, such as depicted in
Figure 2, is peculiar to the near field.

15   Generally, making an exposure mask
takes a very long time and much cost. In the mask
pattern production for near field exposure,
particularly the mask design should be done while
taking into account this electric field
20   distribution.

On the other hand, as the pattern width
to be produced becomes narrower, the mask design
should be made while more exactly taking into
account the extension described above.

25   However, if the mask opening width
having an electric field distribution that can
meet various pattern linewidths and pitches is

sought through complicated simulations using many
varieties of parameters, it takes much time to
complete the simulation and analysis.
Consequently, it causes a problem that the mask
5 designing needs too long time.

[DISCLOSURE OF THE INVENTION]
          It is accordingly an object of the
present invention to provide an exposure mask, an
10 exposure mask designing and manufacturing method,
an exposure method and apparatus, a pattern
forming method and/or a device manufacturing
method, by which at least one of the inconvenience
described above can be solved and by which a mask
15 structure can be accomplished easily while taking
into account the electric field distribution ·
peculiar to the near field, without the necessity
of complicated simulation that requires a long
time.
20   The present invention can provide an
exposure mask, an exposure mask designing and
manufacturing method, an exposure method and
apparatus, a pattern forming method and a device
manufacturing method, which may take the following
25 forms, for example:
          (1)   An exposure mask for exposing an image
forming layer provided on a substrate, by use of

near field light leaking from adjoining openings

formed in a light blocking member, characterized

in that: the light blocking film has an opening

interval that is determined so that an electric

5   field distribution at the image forming layer side

of the opening to be defined as exposure light is

projected on the light blocking member has a

correlation with an eccentric model of electric

field distribution as determined by a linewidth

10   and a height of a pattern to be produced.

(2)   An exposure mask for exposing an image

forming layer provided on a substrate, by use of

near field light leaking from adjoining openings

formed in a light blocking member, characterized

15   in that: a relation $K \geq (W+2T)$ is satisfied where T

is the height of a pattern to be produced by use

of the image forming layer, W is the linewidth of

the pattern, and K is the width of the light

blocking member being present between adjacent

20   openings.

(3)   An exposure mask for exposing an image

forming layer provided on a substrate, by use of

near field light leaking from adjoining openings

formed in a light blocking member, characterized

25   in that: a relation $D \leq (P-W-2T)$ is satisfied where

T is the height of a pattern to be produced by use

of the image forming layer, W is the linewidth of

the pattern, P is the pitch of the pattern, and D is the width of the opening.

(4)   An exposure mask for exposing an image forming layer provided on a substrate, by use of near field light leaking from adjoining openings formed in a light blocking member, characterized in that: a relation $D=\{P-W-2T(1+\alpha)\}$ is substantially satisfied where T is the height of a pattern to be produced by use of the image forming layer, W is the linewidth of the pattern, P is the pitch of the pattern, and D is the width of the opening while taking into account a process margin α after the exposure.

(5)   An exposure mask as recited in item (3) or (4) above, wherein the value of the pitch is made not grater than the wavelength of a surface plasmon polariton wave to be produced on the basis of the light blocking member.

(6)   An exposure mask as recited in any one of items (1) to (5), wherein the openings of the mask have a two-dimensional shape or they are arranged two-dimensionally, with respect to a direction along the surface of the light blocking member where the openings are formed.

(7)   A method of designing an exposure mask for exposing an image forming layer provided on a substrate, by use of near field light leaking from

adjoining openings formed in a light blocking

member, characterized in that: an opening interval

of the light blocking film is determined on the

basis of a linewidth and a height of a pattern to

5   be produced by use of the image forming layer.

(8)   A method of manufacturing an exposure

mask for exposing an image forming layer provided

on a substrate, by use of near field light leaking

from adjoining openings formed in a light blocking

10   member, characterized in that: an opening interval

of the light blocking film is determined on the

basis of a linewidth and a height of a pattern to

be produced by use of the image forming layer, and

that, the light blocking member is subsequently

15   processed so as to obtain the thus determined

opening interval.

(9)   An exposure method for exposing an

image forming layer provided on a substrate, by

use of an exposure mask having a light blocking

20   member with an opening and on the basis of near

field light leaking from the opening,

characterized by: a step of preparing an exposure

mask as recited in any one of items (1) to (6); a

step of approximating the near-field exposure mask

25   and the image forming layer to each other, up to a

distance not greater than a near field region; and

an exposure step for irradiating the image forming

layer with exposure light through the exposure
mask.

(10) An exposure method as recited in item
(9), wherein, where P is the pitch of a pattern to

5   be produced by use of the image forming layer, D
is the width of the opening, W' is the linewidth,
and T' is the pattern height, through adjustment
of an exposure amount in the exposure step and of
another condition or conditions, an exposure is

10   carried out to satisfy a relation $(W'+2T') \leq (P-D)$.

(11) A pattern forming method including an
exposure step for exposing an image forming layer
on the basis of near field light and by use of a
near-field exposure mask having a light blocking

15   member with openings having a pitch P and an
opening width D, and a developing step for
developing the exposed image forming layer,
characterized in that: through adjustment of an
exposure amount in the exposure step and a

20   developing condition in the developing step, a
pattern having a linewidth W and a height T
satisfying a relation $(W+2T) \leq (P-D)$ is produced.

(12) A method as recited in item (11),
wherein, where a minimum value of the height T of

25   the pattern is determined as T'' due to process
after the pattern formation, a pattern having a
linewidth W that satisfies a relation $W \leq (P-D-2T'')$

is produced.

(13) A device manufacturing method
characterized by including an exposure step for
exposing a process object by use of an exposure
5   method as recited in item (9), and a developing
step for developing the exposed process object,
wherein, after these steps, a predetermined
process is conducted to the process object,
whereby a device is manufactured.

10   (14) An exposure apparatus including light
irradiating means and an exposure mask, for   .
exposing a process object provided on a substrate,
by use of near field light leaking from a
plurality of openings formed in a light blocking
15   member of the mask, characterized in that: as the
exposure mask, said exposure apparatus comprises
an exposure mask as recited in any one of items
(1) to (6).

In accordance with the present
20   invention, it is possible to accomplish an
exposure mask, an exposure mask designing and
manufacturing method, an exposure method and
apparatus, a pattern forming method and/or a
device manufacturing method, by which a mask
25   structure can be accomplished easily while taking
into account the electric field distribution
peculiar to the near field, without the necessity

of complicated simulation that requires a long
time. Therefore, design and production of a near-
field exposure mask can be achieved efficiently.
Particularly, in the production of a desired fine
5   pattern not greater than the wavelength of light
used for the exposure, the throughput can be
improved significantly and, thud, the cost can be
decreased well.

These and other objects, features and
10   advantages of the present invention will become
more apparent upon a consideration of the ,
following description of the preferred embodiments
of the present invention taken in conjunction with
the accompanying drawings.

15

[BRIEF DESCRIPTION OF THE DRAWINGS]

Figure 1 is a schematic view for
explaining the present invention and, specifically,
it illustrates how to determine an opening width
20   of a near-field exposure mask on the basis of a
concentric-circle model.

Figure 2 is a schematic view for
explaining the present invention and, specifically,
it illustrates a simulation result that shows an
25   electric field intensity produced adjacent the
openings.

Figure 3 is a schematic view for

explaining the present invention and, specifically, it illustrates a simulation result that shows an electric field intensity produced adjacent the openings, as well as a concentric-circle model.

5   Figure 4 is a schematic view for explaining how to determine an opening width of a near-field exposure mask on the basis of a concentric-circle model, in accordance with an embodiment of the present invention.

10   Figure 5 is a schematic view of a general structure of a near-field exposure mask according to an embodiment of the present invention.

         Figure 6 is a sectional view showing a

15 general structure of a near-field exposure apparatus according to an embodiment of the present invention.

         Figure 7 is a graph illustrating a solubility curve of a certain resist.

20   Figure 8 is a schematic view for explaining a pattern width W' produced through near field exposure in accordance with an embodiment of the present invention.

         Figures 9A - 9C' illustrate examples of

25 resist patterns which are obtainable from masks having a two-dimensional shape pattern, wherein Figures 9A and 89' are a case where a mask pattern

having a grid-like fine openings is used, wherein

Figures 9B and 9B′ are a case where a mask having

a two-dimensional fine opening array is used, and

wherein Figures 9C and 9C′ are a case wherein a

5   mask whose light blocking metal film has a two-

dimensional rectangular array is used.

        Figures 10A and 10B illustrate a resist

pattern obtainable when a mask having a two-

dimensional shape pattern is used, and

10   specifically, Figure 10A shows a resist pattern

obtainable where a mask that has a light blocking

metal film having a ring-like shaped is used.

        Figure 11 is a schematic view for

explaining the present invention and, specifically,

15   it illustrates how to determine a minimum value of

opening interval of a near-field exposure mask in

accordance with a concentric-circle model.

[BEST MODE FOR PRACTICING THE INVENTION]

20   In accordance with the present

invention, it is enabled to provide an exposure.

mask, an exposure mask designing and manufacturing

method, an exposure method and apparatus, a

pattern forming method and/or a device

25   manufacturing method, by which a mask structure

can be accomplished easily while taking into

account the electric field distribution peculiar

to the near field, without the necessity of
complicated simulation that requires a long time.
This is based on the following findings acquired
by the inventors of the present invention.

5   Namely, in the mask designing taking
into account the extension peculiar to the near
field, from simulations it has been found that the
electric field distribution adjacent the opening
of a mask from which near field light emits takes

10   the form of an electric field distribution having
an approximately concentric extension.. Also, it
has been found that such electric field
distribution can be approximated by a concentric-
circle model, and that, by using such concentric-

15   circle model and from the pattern width W and
pattern height T (pitch P in the case of a
periodic pattern), the structure of a near-field
exposure mask to be prepared can be determined
easily by equations, without the necessity of

20   simulations.

          This will be explained in greater
detail.

          Figure 2 shows a near-field electric
field distribution produced near fine openings.

25   This is the result of simulation made by use of a
kind of GMT (Generalized Multipole Technique)
program, that is, "Max-1" (C.IIafner, Max-1, A

Visual Electromagnetics Platform, Wiley,

Chichester, UK, 1998). GMT is one analysis method

of Maxwell equation, wherein a scattered wave is

described while a multipole is placed as a virtual

5   source. As regards a mask base material 102, SiN

was used and, regarding a light blocking film 101,

Cr was used. The pitch of the fine opening

pattern was 200 nm, and the opening width was 70

nm. The incident wavelength was 436 nm.

10   Numerical values (0.2, 0.4, 0.6, ...

1.0, 1.2, and so on) in the drawing are a relative

electric field intensity where the electric field

intensity of the incident light is taken as 1.0.

            Figure 2 in fact illustrates an

15   electric field distribution peculiar to the near

field, wherein the intensity decreases as like an

exponential function, as becoming away from the

fine opening. Analyzing this distribution in

greater detail, it has been found that the

20   electric field intensity takes a peak value at an

edge portion, at the light blocking film, of the

fine opening and, from there, the intensity

attenuates as like expanding as a concentric

circle. Also, it has been found that, even with a

25   different opening width or opening interval or a

different pitch pattern, simulation of electric

field distribution to the near-field mask shows

similar results, particularly when, for a periodic

pattern, the pitch of the fine opening pattern is

not greater than the surface plasmon polariton

wave and the light blocking film is made of a

5   different material, that is, Au or Ta.

In the present invention, the term

"opening width" refers to the width of an opening

defined by forming a light blocking film,

constituting a mask, where no light blocking film

10   is present there. Specifically, in Figure 1, for

example, the portion denoted at Dmax corresponds

to it. Also, the term "opening interval" refers

to the distance between two adjacent openings,

that is, the width of the light blocking film

15   there. Specifically, in Figure 11, for example,

the portion denoted at Kmin corresponds to it.

Modeling such distribution, Figure 3

illustrates a combined result of a modeled near-

field distribution (right-hand side of Figure 3)

20   and the simulation results of Figure 2 (left-hand

side of Figure 3). In Figure 3, for simplicity of

illustration, a portion of the field contour line

shown in Figure 2 is omitted.

It is seen from Figure 3 that, through

25   a concentric-circle model 600, distribution

adjacent the light blocking film edge portion and

distribution from the edge portion to a portion

601, below the light blocking film, are quite well approximated. Namely, the concentric-circle model 600 well depicts the feature that the extension distance in the film-thickness direction (downward

5   direction in Figure 3) in the simulation result and the extension distance in a direction parallel to the mask surface (horizontal direction as viewed in Figure 3) are similar to each other.

To the contrary, in this model, except

10   the light blocking film edge portion and the portion from the edge portion to the portion below the light blocking film, that is, at a portion below the opening (as long as a produced pattern of exposure concerns), the electric field

15   distribution is not approximated well. Particularly, as the opening width becomes wider, the electric field intensity distribution deviates off the model. Since, however, from the simulation result, there is a tendency that the

20   electric field intensity below the opening increases as the opening width becomes wider, it can be considered that the portion below the opening is exposed constantly. Actually, in practical experiments, a result corresponding to

25   the simulation result was obtained at the portion blow the opening.

By using this model, the structure of a

near-field exposure mask to be prepared in order

to obtain a desired pattern can be determined

without the necessity of complicated and massive

simulations using various parameters and analysis

5   of the results. This will be described in detail,

below.

Once the type of the image forming

layer is fixed, the pattern to be produced in the

image forming layer can be determined by exposure

10   amount and developing condition. Thus, where an

electric field distribution having a concentric

extension as of the above-described model is

produced, the pattern width thereof can have a

freedom if the exposure amount and developing

15   condition are chosen appropriately.

First of all, a case where a desired

pattern to be produced is a periodic pattern will

be explained. For a periodic pattern having a

pitch P, also the pitch of the mask fine opening

20   pattern should be equal to P. For production of

one having a pattern width W, from the concentric-

circle model described above, a relation of the

following equation (1) should be satisfied between

the maximum value Dmax of the mask opening width

25   and the film thickness T of the image forming

layer:

$$Dmax = P-W-2 \times T \qquad \qquad ...(1)$$

If the relation is described with
respect to D as the mask opening width is not
limited to a maximum value, it can be set forth as
follows:

5          $D \leq P-W-2T$

Here, T is the pattern height of the
image forming layer 401 as determined by a
subsequent process or processes.

Figure 1 shows the relationship of
10   values in equation (1). Thus, referring to the
drawing, equation (1) will be explained in greater
detail. First, the pattern height T of the image
forming layer 401 by which a desired processing
depth of a process object substrate 402 can be
15   processed, is determined on the basis of a process
condition such as etching durability, for example.
In order to make a pattern of this height T, it is
necessary that a pattern after development is
produced at the field contour line portion outside
20   the field contour line 800, depicted by a thick
line in Figure 1.

The electric field distribution below
the light blocking film 101 is well approximated
by a concentric-circle model 600, as described
25   hereinbefore. It is seen from Figure 1 that the
extension from the edge portion of the light
blocking film 1 is approximately even both in

regard to the film thickness direction (downward
direction as viewed in Figure 1) and in a
direction parallel to the mask surface (horizontal
direction as viewed in Figure 1). Therefore, if a

5   pattern after development is produced at the
electric field contour line 800 or any electric
field contour line outside the line 800, it
assures a result that a developed pattern having
an extension not less than a distance T, from the

10   edge portion of the light blocking film 101, even
in the direction parallel to the mask surface, is
produced.

The extension phenomenon from the edge
portion of the light blocking film 101 similarly

15   occurs at the opposite side edge of the light
blocking film 101.

Thus, the largest opening width Dmax of
the near-field exposure mask, effective to produce
a pattern having a pattern width W just underneath

20   the light blocking film 101, can be set as defined
in equation (1), by using the pattern pitch P,
width W and height T.

As regards the image forming layer, any
material may be used provided that reaction occurs

25   in response to the near field from the opening and
it can bear a process after the pattern formation.
As regards the versatility, however, use of

- 21 -

photoresist is preferable.

The value T may be determined by a
process or processes after the pattern formation
and, more specifically, the etching durability in
5   the etching process for the process object
substrate, or the film thickness of vapor
deposition in the lift-off, for example.

Although it is desirable that a pattern
of a thickness having a durability to the
10   processing for the process object substrate can be
produced only by the image forming layer, if a
thickness not less than (P-W)/2 is necessary, a
buffer layer may be prepared between the image
forming layer 401 and the process object substrate.

15   The buffer layer may be a resist layer,
an oxide film layer, or a metal layer, for example,
not processed or, alternatively, processed so as
to provide a physical property different from the
image forming layer, such as, for example, hard
20   baking or non-silylating in a case where a surface
imaging method (e.g. multilayer resist method or
surface layer silylating method), for example, is
used. The buffer layer may be a single layer or
it may comprise plural layers. By transferring a
25   pattern, having been formed in the image forming
layer 401 on the basis of near field exposure, to
such buffer layer in accordance with a method such

as dry etching method, for example, one having a
thickness sufficiently durable to the processing
to be made to the process object substrate can be
produced.

5   The value by which the opening width D
becomes equal to Dmax is the value by which the
process margin becomes equal to zero. In this
specification, the term "process margin" refers to
a factor that defines the tolerance of process

10   with which a desired pattern height T and a
desired pattern linewidth can be assuredly
obtainable even taking into account a process to
be performed after the exposure.

          The process margin "zero" means that

15   the margin for the process condition such as
exposure developing condition for the pattern
formation or the process after the pattern
formation, such as etching or vapor deposition, is
zero. With such "zero" margin, actually it is

20   very difficult to perform the pattern formation
and subsequent processes for the process object
substrate.

          Therefore, while taking into account
the process margin, the value of the opening width

25   D should desirably be made smaller than Dmax, as
given by equation (2) below:

$$D = P-W-2T(1+\alpha) \qquad \qquad ...(2)$$

wherein α is the process margin. More
specifically, it may be a component of overall
film thickness dissolution during the development
of image forming layer, or a component of

5   dissolution in a direction parallel to the
substrate surface during the development of the
image forming layer, for example.

While the value α varies largely with
the process, in many cases it takes a value of

10   $0 < \alpha \leq 4$. If equation (2) takes a negative value in
dependence upon the value of α, a buffer layer may
be provided between the image forming layer and
the process object substrate as described
hereinbefore, to reduce the values of α and T of

15   the effective image forming layer, such that the
opening width D having an effective and positive
value can be set.

Figure 4 shows the relationships of
these values. The reference "αp" in Figure 4 is a

20   value as determined by a relation $0 \leq \alpha p \leq \alpha$. While α
is defined as the process margin, not only it
includes the margin with respect to the film
thickness direction but also it embraces the
margin with respect to a direction along the mask

25   surface. Thus, the component αp of margin α only
in the film thickness direction is added to the
pattern height T.

A near-field exposure mask having an
opening pattern pitch P and an opening width D,
having been designed in the manner described above,
is manufactured, and near-field exposure and

5   development are carried out by use of the mask, by
which a fine pattern can be produced. Details
will be described below.

Figure 5 illustrates a general
structure of a near-field exposure mask according

10   to an embodiment of the present invention. The
near-field exposure mask 1 comprises a light
blocking film 101, a mask base material 102 and a
mask supporting member 103. A thin film portion
104 that presents an effectual near-field exposure

15   mask, contributable to exposure, is defined by
supporting the mask base material 102 through the
mask supporting member 103. The light blocking
film 101 may comprise a material having a low
transmissivity to exposure light to be described

20   later, such as Cr, Al, Au or Ta, for example.

The mask base material 102 may comprise
a material having a transmissivity to exposure
light to be described later, such as SiN, SiO_2, or
SiC, for example, having a property different from

25   the light blocking film 101. There are fine
openings 105 formed in the light blocking film 101,
the openings having a shape like a slit or bore.

These openings are formed in the thin film portion
104 constituted by the light blocking film 101 and
the mask base material 102 only. As will be
described later, these openings are provided so as
5   to produce near field light (evanescent light) at
a front surface of the mask in response to
irradiation of the mask exposure light from the
rear surface of the mask (upper surface thereof in
Figure 1).

10   The pitch and opening width of the fine
opening pattern of the near-field exposure mask
are made to be equal to P and D having been
designed as described hereinbefore.

               The opening pattern may be formed by
15   use of a processing machine such as FIB, EB, X-ray
or SPM, or in accordance with a nano-imprint
method or a fine pattern forming method based on
near field exposure.

               Next, referring to Figure 6, a method
20   of producing a fine pattern by use of an exposure
apparatus 2, which is an example for performing
exposure with use of an exposure mask 1 as has
been described above, will be explained.

               Figure 6 is a sectional view showing a
25   general structure of an exposure apparatus 2
according to an embodiment of the present
invention. As shown in Figure 2, the exposure

- 26 -

apparatus 2 comprises a light source unit 200, a collimator lens 300, an exposure mask 100, an exposure object 400 to be exposed, and a pressure adjusting system 500.

5   Regarding major components of the exposure apparatus 2, the exposure apparatus 2 is arranged so that, by using the exposure mask 100 that corresponds to the whole surface of the exposure object 400, a predetermined pattern

10   formed on the exposure mask 100 is transferred to the exposure object 400 at once.

The present embodiment can be accomplished with various exposure methods such as, for example, a step-and-repeat exposure method

15   wherein an exposure mask 100 smaller than an exposure object 100 is used and wherein exposure of a portion of the exposure object is carried out repeatedly while changing the position of the exposure subject 400, or a step-and-scan exposure

20   method.

Here, the term "step-and-scan exposure method" refers to such projection exposure method that: an exposure mask 100 corresponding to one shot (one shot region covers one or more chip

25   regions) is disposed opposed to one shot region of an exposure object 400, and the exposure mask 100 and the exposure object 400 are relatively and

continuously scanned by exposure light, whereby a
pattern of the exposure mask 100 is
lithographically transferred onto the exposure
object; while on the other hand, after completion

5   of exposure of one shot, the exposure object 400
is moved stepwise so that a subsequent shot region
of the exposure object 400 is disposed opposed to
the exposure mask 100, and then the scanning
exposure process described above is repeated.

10   Also, the term "step-and-repeat
exposure method" refers to such projection
exposure method that: each time simultaneous
exposure of one shot of an exposure object 400 is
completed, the exposure object 400 is moved

15   stepwise to move the same to the exposure region
of a subsequent shot (i.e. the position to be
opposed to the exposure mask 100), and then the
simultaneous exposure is repeated.

                    In this embodiment, where the step-and-

20   scan exposure method or step-and-repeat exposure
method is to be carried out, for every stepwise
motion, separation operation of the mask from the
exposure object 400 should be done before the
stepwise motion and also intimate-contacting

25   operation of the mask to the exposure object 400
should be done after the stepwise motion.

                    The light source unit 200 has a

function for producing illumination light for
illuminating the exposure mask 100 having formed
thereon a transfer circuit pattern to be
transferred to the substrate. As an example, it

5   may comprise an Hg lamp as a light source that
can emit ultraviolet light. However, the lamp is
not limited to the Hg lamp, but xenon lamp or
deuterium lamp, for example, may be used. Also,
there is no restriction in regard to the number of

10 light sources.

Further, the light source to be used in
the light source unit 100 is not limited to lamp,
but one or more lasers may be used. For example,
a laser that can emit ultraviolet light or soft X-

15 rays may be used. ArF excimer laser having a
wavelength of about 193 nm, KrF excimer laser
having a wavelength of about 248 nm, or F2 excimer
laser having a wavelength of about 153 nm, for
example, may be used. The type of laser is not

20 limited to excimer laser, and YAG laser, for
example, may be used. There is no restriction in
regard to the number of lasers.

The collimator lens 300 functions to
transform the illumination light emitted from the

25 light source unit 200 into parallel light which in
turn is introduced into a pressuring vessel 510 of
the pressure adjusting system 500, whereby the

whole surface of the exposure mask 100 or only a
portion thereof which is going to be exposed is
illuminated with uniform light intensity.

As has been described with reference to
5   Figure 5, the exposure mask 100 comprises a light
blocking film 101, a mask base material 102, and a
mask supporting member 103. From the light
blocking film 101 and the mask base material 102,
a thin film 104 being elastically deformable is
10   provided. The exposure mask 100 is arranged so
that a pattern as defined by the fine opening
pattern 105 of the thin film 104 is transferred to
the image forming layer 401 at a unit
magnification, on the basis of near field light.
15   Here, the term "unit magnification" does not mean
exact "1x" magnification, but it is mentioned to
emphasize that the magnification differs from that
in the transfer by reduction projection.

Regarding the exposure mask 100, the
20   lower surface thereof as viewed in Figure 6 is the
front surface of the mask as being mounted. The
light blocking film 101 is disposed outside the
pressuring vessel 510 of the pressure adjusting
system 500. The thin film 104 can be elastically
25   deformed to assure close contact with any surface
irregularities of the image forming layer 401 or
with any waviness of the exposure object 400.

The exposure object 400 comprises a
process object substrate such as a wafer, for
example, and an image forming layer 401 applied
thereto. The exposure object 400 is mounted on a
5   stage 450.

As regards the image forming layer 401,
use of a photoresist to be used in ordinary
photolithography is preferable. As regards the
resist material, use of one having a large
10   contrast value is preferable. The film thickness
of the resist is T, as described hereinbefore.
The application procedure for the image forming
layer 401 includes a pre-process, a resist coating
process and a pre-baking process.

15   The process object substrate can be
chosen from a wide variety of materials such as
semiconductor substrate (e.g. Si, GaAs or InP),
insulative substrate (e.g. glass, quartz or BN),
or one provided by such substrate material and
20   having a film of metal, oxide or nitride, for
example, formed thereon. However, it should be
intimately contacted to the exposure mask 100
throughout the whole exposure region with a
clearance of preferably not greater than 10 nm,
25   and at least not greater than 100 nm. Therefore,
for the substrate 402, one having a good flatness
as much as possible should be chosen.

During the exposure, the image forming

layer 401 and the exposure mask 100 should be

close to each other for execution of exposure

based on the near field light, and they are

5   relatively approximated to each other up to a

clearance of about 100 nm or less.

The stage 450 is driven by an external

equipment, not shown. It functions to align the

exposure object 400 relatively and two-

10   dimensionally with respect to the exposure mask

100, and also it operates to move the exposure

object 400 upwardly and downwardly as viewed in

Figure 3.

The stage 450 of this embodiment has a

15   function for moving the exposure object 400

between a loading/unloading position (not shown)

and the exposure position shown in Figure 3. At

the loading/unloading position, a fresh exposure

object 400 not having been exposed is loaded on

20   the stage 450 while, on the other hand, an

exposure object 400 having been exposed is

unloaded therefrom.

The pressure adjusting system 500

serves to facilitate good intimate contact and

25   separation between the exposure mask 100 and the

exposure object 400, more particularly, between

the thin film portion 104 and the image forming

layer 401. If both of the surfaces of the

exposure mask 100 and the image forming layer 401

are completely flat, they can be brought into

intimate contact with each other throughout the

5   entire surface, by engaging them with each other.

Actually, however, the surfaces of the exposure

mask 100, the image forming layer 401 and

substrate 402 have a surface irregularity or

surface waviness. Therefore, only by

10   approximating them toward each other and bringing

them into engagement with each other, the result

would be mixed distribution of intimate contact

portions and non-intimate contact portions. In

the non-intimate contact portion, the exposure

15   mask 100 and the exposure object 400 are not held

within a range of distance through which the near

field light effectively functions. Therefore, it

would result in exposure unevenness.

In consideration of it, the exposure

20   apparatus 2 of this embodiment is provided with a

pressure adjusting system 500 which comprises a

pressurizing vessel 510, a light transmission

window 520 made of a glass material, for example,

pressure adjusting means 530, and a pressure

25   adjusting valve 540.

The pressurizing vessel 510 can keep

the gas-tightness through the combination of the

light transmission window 520, the exposure mask
100 and the pressure adjusting valve 5540. The
pressurizing vessel 510 is connected to the
pressure adjusting means 430 through the pressure
5   adjusting valve 5540, such that the pressure
inside the pressurizing vessel 510 can be adjusted.
The pressure adjusting means 530 may comprise a
high-pressure gas pump, for example, and it
functions to increase the inside pressure of the
10 pressurizing vessel 510 through the pressure
adjusting valve 540.

        The pressure adjusting means 530
further comprises an exhausting pump (not shown),
so that it can function to decrease the inside
15 pressure of the pressurizing vessel 510 through a
pressure adjusting valve, not shown.

        The adhesion between the thin film and
the image forming layer 401 can be adjusted by
adjusting the inside pressure of the pressurizing
20 vessel 510. If the surface of the exposure mask
100, the image forming layer 401 or of the
substrate 402 has slightly large surface
irregularities or waviness, the inside pressure of
the pressurizing vessel 510 may be set at a higher
25 level to increase the adhesion strength, thereby
to reduce dispersion of clearance between the
surfaces of the mask surface 100, the image

forming layer 401 and the substrate 402 due to the
surface irregularities or waviness.

As an alternative, the front surface
side of the exposure mask 100 as well as the image

5   forming layer 401 and the substrate 402 side may
be disposed inside a reduced-pressure vessel 510.
In that occasion, on the basis of a pressure
difference with an atmospheric pressure, higher
than the vessel inside pressure, a pressure may be

10   applied to the exposure mask from its rear surface
side to its front surface side, whereby the
adhesion between the exposure mask 100 and the
image forming layer 401 can be improved. Anyway,
a pressure difference that the pressure at the

15   rear surface side of the exposure mask 100 is
higher than the pressure at the front surface side
thereof, is produced. If the surface of exposure
mask 100 or the surface of image forming layer 401
or substrate 401 has slightly large surface

20   irregularities or waviness, the pressure inside
the reduced pressure vessel may be set at a lower
level to increase the adhesion, thereby to reduce
dispersion of clearance between the mask surface
and the resist surface or substrate surface.

25   As a further alternative, the inside of
the pressurizing vessel 510 may be filled with a
liquid which is transparent with respect to the

exposure light EL and, by using a cylinder (not shown), the pressure of the liquid inside the pressurizing vessel 510 may be adjusted.

Next, the sequence of exposure using the exposure apparatus 2 will be explained.

For exposure, the stage 450 aligns the exposure object 400 with respect to the exposure mask 100 relatively and two-dimensionally.

If the alignment is completed, the stage 450 moves the exposure object 400 along a direction of a normal to the mask surface, into a range that, throughout the entire surface of the image forming layer 401, the clearance between the image forming layer 401 and the exposure mask 100 is reduced to not greater than 100 nm so that they can be intimately contacted to each other on the basis of elastic deformation of the thin film 104.

Subsequently, the exposure mask 100 and the exposure object 400 are brought into intimate contact with each other. Specifically, the pressure adjusting valve 540 is opened and the pressure adjusting means 530 introduces a high pressure gas into the pressurizing vessel 510, whereby the inside pressure of the pressurizing vessel 510 is raised. After this, the pressure adjusting valve 540 is closed.

As the inside pressure of the

pressurizing vessel 501 increases, the thin film

104 is elastically deformed and it is pressed

against the image forming layer 401.

As a result, the thin film 104 is

5   closely contacted to the image forming layer 401

with uniform pressure, throughout the entire

surface and within a range in which the near field

light effectively acts on the image forming layer.

Where pressure application is performed in the

10   manner described above, in accordance with the

Pascal's principle the repulsive force acting on

between the thin film 104 and the image forming

layer 401 becomes uniform. This effectively

avoids a phenomenon that a large force is locally

15   applied to the thin film 104 or the image forming

layer 401, and thus it effectively prevents local

breakage of the exposure mask 100 or the exposure

object 400.

In this state, the exposure process is

20   carried out. Namely, exposure light is emitted

from the light source unit 200 and it is

transformed into parallel light by means of the

collimator lens 300. Then, the exposure light is

introduced into the pressuring vessel 510 through

25   the glass window 520. The thus introduced light

passes through the exposure mask 100, disposed

inside the pressurizing vessel 510 from its rear

surface side to its front surface side, that is, from the upper side to the lower side in Figure 3, whereby near field light leaking from the pattern defined by the fine openings of the thin film 104

5 is produced.

The near field light is scattered within the image forming layer 401, such that the image forming layer is exposed thereby. Where the thickness of the image forming layer 401 is

10 sufficiently thin, the scatter of near field light within the image forming layer 401 does not expand largely, such that a pattern corresponding to the fine opening, smaller than the wavelength of exposure light, can be transferred to the image

15 forming layer 401.

After the exposure is completed, a valve (not shown) is opened and the inside of the pressurizing vessel 510 is evacuated through an exhaust pump (not shown) of the pressure adjusting

20 means 530, thereby to decrease the pressure of the pressurizing vessel 510. Then, the thin film 104 is separated (or peeled) off from the image forming layer 401 on the basis of elastic deformation.

25 Where pressure reduction is performed in the manner described above, in accordance with the Pascal's principle the repulsive force acting

on between the thin film 104 and the image forming

layer 401 becomes uniform. This effectively

avoids a phenomenon that a large force is locally

applied to the thin film 104 or the image forming

5   layer 401, and thus it effectively prevents local

breakage of the exposure mask 100 or the exposure

object 400.

After this, the exposure object 400 is

moved by the stage to the loading/unloading

10   position where it is replaced by a fresh exposure

object 400. Subsequently, a similar procedure is

repeated.

Here, the exposure amount can be set in

the following manner.

15   The electric field distribution where a

near field exposure mask prepared as described

above can be determined on the basis of simulation.

Furthermore, if the relationship of the remaining

film thickness after development with respect to

20   the exposure amount of the used image forming

layer, namely, the solubility curve of the resist,

is predetected, on the basis of it, the exposure

amount and the developing condition are determined

so that a desired pitch P and a desired pattern

25   width W are obtained.

More specifically, first of all, from

the simulation result, the electric field contour

line where a desired pattern width is obtainable
when the intensity of incident light upon the
near-field exposure mask is taken as 1, is read
out. This is denoted by "x". Also, from the

5   resist solubility curve, the exposure amount with
which the standardized remaining film thickness
becomes equal to 0.5 is read out. This is denoted
by "I".

As an example, Figure 7 shows a

10 solubility curve of a representative resist. If a
used resist is a negative resist, the above value
takes the same value of the sensitivity. If it is
a positive resist, the above value takes a value
as designated in Figure 7 by an inclined arrow.

15   If the intensity of incident light on
the near-field exposure mask is J, then J and t
that satisfy the relation:

$$I = xJt \qquad \qquad \ldots (3)$$

are set as the intensity of incident light and the

20 exposure time, respectively. Namely, Jt is set as
the exposure amount.

As an example, a case will be explained
in more detail with reference to Figure 4.

First, an electric field contour line

25 800 with which a desired pattern width is
obtainable is chosen. Regarding the contour line
800, from the simulation result, the intensity

thereof was 0.5 where the incident intensity was taken as 1. Also, from the solubility curve of a used resist, the exposure amount with which the standardized remaining film thickness became equal

5   to 0.5 was 220 mJ/cm^2. Where light of 200 mW/cm^2 is used as the incident intensity, if follows from equation (3) that:

$$220 = 0.5 \times 200 \times t$$

such that an exposure time 1.2 sec. and an

10   exposure amount 240 mJ/cm^2 are calculated.

It is sufficient that the simulation is done only in regard to a near-field exposure mask having already determined pitch and opening width, that is, only with regard to one condition.

15   Further, the number of parameters required for conditioning the process is much reduced. Therefore, the time from a desired pattern is given to completion of actual manufacture, is reduced considerably.

20   On the other hand, in regard to a near-field mask having already determined pitch and opening width, without simulation the exposure amount and developing condition with which a desired pattern width W is obtainable can be

25   determined on the basis of a formed pattern produced when the exposure amount and developing condition are changed. Since there is no

necessity of repeatedly performing complicated

simulations with various parameters, in the design

of near field exposure mask, the time required for

the mask designing is reduced remarkably.

5   By developing the resist having a

latent image formed therein in the manner

described above, a fine resist pattern of a

desired size can be produced. Thereafter, an

appropriate process to the substrate such as dry

10   etching, wet etching, or lift-off, for example, or

transfer to a background resist layer, may be

carried out.

A specific example of the present

invention will be explained, while specifying its

15   numerical values.

As an example, a periodic slit

structure having a pitch 200 nm and a pattern

width 20 nm is going to be produced upon an SIO

(silicon-on-insulator) wafer having an SIO layer

20   of 100 nm thickness. Applying this to the

aforementioned symbols, it follows that P = 200 nm

and W = 20 nm.

In order that the process object

substrate is an SIO layer, i.e. Si layer, and that

25   the Si layer is etched through a depth 100 nm,

taking into account the margin of dry etching, the

resist layer as the mask layer should have a

thickness of not less than 100 nm. Thus, it
follows that:

$$T(1+\alpha) = 100 \text{ nm}$$

Applying this to equation (2), the

5   left-hand term becomes negative and, thus, a
buffer layer is provided between the image forming
layer and the process object substrate. More
specifically, a dual-layer resist method is used.
A hard-baked resist layer is formed as a buffer

10   layer upon the process object substrate, with a
thickness 100 nm. On this layer, a Si-containing
resist is formed as an image forming layer, with a
thickness 20 nm. The thickness is set so that the
image forming layer functions as an etching mask

15   when the image forming layer pattern is
transferred to the hard-baked layer. Specifically,
$T = 20$ nm.

Regarding the process margin, when $\alpha =$
1.5 is chosen from its range "$0 \leq \alpha \leq 4$", from

20   equation (2) the mask opening width D [nm] can be
given by:

$$D = 200-20-2 \times 20 \times (1+1.5) = 80$$

In consideration of this, a mask having a pitch
200 nm and an opening width 80 nm was made as a

25   near field exposure mask.

Using this mask, a buffer layer and an
image forming layer set as has been described

above were produced on the Si layer. Through

exposure and development, a pattern having a pitch

200 nm was produced in the image forming layer.

Using this as an etching mask, an etching process

5 was carried out with a dry etching apparatus and

an oxygen gas, a slit pattern having a pitch 200

nm and a pattern width 20 nm was produced on the

buffer layer.

Further, using the pattern of the

10 buffer layer as an etching mask, Si was etched

with a dry etching apparatus, whereby a fine Si

structure having a pitch 200 nm, a pattern width

20 nm and a pattern height 100 nm was produced

upon an insulative film.

15   By the way, where a mask having any one

of a variety of two-dimensionally shaped mask

patterns 801 such as shown in Figures 9 and 10 is

applied to a near-field exposure mask of the

present invention such as described hereinbefore,

20 just underneath the mask a latent image of two-

dimensional shape such as illustrated at 803 is

produced. After exposure and development, a

resist pattern 802 corresponding to it is produced.

For example, with a mask pattern having

25 grid-like fine openings (Figure 9A), a two-

dimensional dot array (in the case of positive

type resist) such as shown in Figure 9A' or a hole

array (in the case of negative type resist) is
obtainable. These patterns may be suited for
production of a two-dimensionally arrayed quantum
dot array to be used for an optical device or
5   electronic device having quantum dots.

On the other hand, with a mask pattern
having a two-dimensional fine-opening array such
as shown in Figure 9B, a two-dimensional grid-like
array (in the case of positive type resist) such
10   as shown in Figure 9B' or a hole array (in the
case of negative type resist) is obtainable.

In the case of a mask pattern wherein a
light blocking metal film portion has a two-
dimensional rectangular array such as shown in
15   Figure 9C, a two-dimensional fine-line pair (in
the case of positive type resist) such as shown in
Figure 9B' or a fine groove array (in the case of
negative type resist) is obtainable. These
patterns may be suited for production of a gate
20   pattern to be used in a CMOS electronic device.

Further, in the case of a mask pattern
wherein a light blocking metal film portion has a
ring-like shape, such as shown in Figure 10A, a
two-dimensional dot or ring array (in the case of
25   positive type resist) such as shown in Figure 10B
or a hole or ring array (in the case of negative
type resist) is obtainable.

The foregoing description has been made with reference to a method of producing a pattern having a desired pitch P, a desired pattern width W and a desired pattern height T by use of a near

5   field exposure mask having an opening width D designed and manufactured as described hereinbefore. However, on the basis of a method such as adjusting the exposure amount, changing the used resist, changing the developing condition

10 or the like, a pattern having either one or both of a pattern width W' and a pattern height T' different from W and T and satisfying the following relation, may be manufactured:

$$(W'+2T') \leq (P-D) \qquad \ldots (4)$$

15 As an example, the exposure amount may be increased as compared with the method having been described hereinbefore, or the sensitivity of a used resist may be increased, or the developing time may be increased. Any one of them or two of

20 them may be performed and, in that occasion, a pattern having a pattern width W' satisfying a relation W'<W, even for the same pattern height, i.e. T=T', is obtainable.

Furthermore, a pattern having a pattern

25 width W' satisfying a relation W'>W is obtainable when any one or two of (i) choosing the image forming layer height satisfying T'<T and

developing the exposure amount, (ii) decreasing
.the resist sensitivity, and (iii) shortening the
developing time.

5   An example will be explained in detail,
with reference to Figure 8. Where a desired
pattern height T' is equal to T, an electric field
contour line 801 (depicted by a thick line in
Figure 8) which is outside the electric field
contour line 800 (depicted by a thick line in
10   Figure 1), is chosen. Subsequently, the above-
described exposure amount and developing condition
are set to assure that a pattern can be produced
with the field contour line 801. If a used
material of the image forming layer 401 is the
15   same, by increasing the exposure amount, for
example, a pattern having a pattern width W'
different from W and satisfying a relation W'<W
can be produced from an already prepared mask
having a pitch P and an opening width Dmax. Here,
20   the values of W' and T'(=T) satisfy equation (4).
         Subsequently, a case where a desired
pattern to be produces is an isolated pattern,
will be explained. In order to produce a pattern
having a pattern width W, from the concentric-
25   circle model described hereinbefore, a relation
(5) below should be satisfied between a minimum
value Kmin of the mask opening interval and the

film thickness T of the image forming layer.

Kmin = W+2T   ...(5)

Describing it as K where the mask opening interval is not limited to a minimum value,

5   it follows that:

K ≥ W+2T

Figure 11 shows the relationship of the values in equation (5). Thus, referring to the drawing, equation (5) will be explained in more

10 detail.

First, the pattern height T of the image forming layer 401 by which a desired processing depth of a process object substrate 402 can be processed, is determined on the basis of a

15 process condition such as etching durability, for example. In order to make a pattern of this height T, it is necessary that a pattern after development is produced at the field contour line portion outside the field contour line 800,

20 depicted by a thick line in Figure 11.

The electric field distribution below the light blocking film 101 is well approximated by a concentric-circle model, as described hereinbefore. It is seen from Figure 11 that the

25 extension from the edge portion of the light blocking film 101 is approximately even both in regard to the film thickness direction (downward

direction as viewed in Figure 11) and in a
direction parallel to the mask surface (horizontal
direction as viewed in Figure 11). Therefore, if
a pattern after development is produced at the
5   electric field contour line 800 or any electric
field contour line outside the line 800, it
assures a result that a developed pattern having
an extension not less than a distance T, from the
edge portion of the light blocking film 101, even
10 in the direction parallel to the mask surface, is
produced.

The extension phenomenon from the edge
portion of the light blocking film 101 similarly
occurs at the opposite side edge of the light
15 blocking film 101.

Thus, the minimum opening interval Kmin
of the near-field exposure mask, effective to
produce a pattern having a pattern width W just
underneath the light blocking film 101, can be set
20 as defined in equation (5), by using the pattern
width W and height T.

The value by which the opening interval
K becomes equal to Kmin is the value by which the
process margin becomes equal to zero. The process
25 margin "zero" means that the margin for the
process condition such as exposure developing
condition for the pattern formation or the process

after the pattern formation, such as etching or
vapor deposition, is zero. With such "zero"
margin, actually it is very difficult to perform
the pattern formation and subsequent processes for
5   the process object substrate.

          Therefore, while taking into account
the process margin, the value of the opening
interval K should desirably be made not less than
Kmin, as given by equation (6) below:
10          $K = W+2T(1+\alpha)$ ...(6)
wherein α is the process margin. More
specifically, it may be an increment of film
thickness affording a margin to the etching
durability to the etching of the substrate or a
15 background resist, an increment of film thickness
of vapor deposition in the lift-off, a component
of overall film thickness dissolution during the
development of image forming layer, or a component
of dissolution in a direction parallel to the
20 substrate surface during the development of the
image forming layer, for example.

          While the valueα varies largely with
the process, in many cases it takes a value of
$0<\alpha\leq4$. If equation (6) takes a negative value in
25 dependence upon the value of α, a buffer layer may
be provided between the image forming layer and
the process object substrate as described

hereinbefore, to reduce the values of α and T of
the effective image forming layer, such that the
opening interval K having an effective and
positive value can be set.

5   A near-field exposure mask having an
opening interval K, having been designed in the
manner described above, is manufactured, and near-
field exposure and development are carried out by
use of the mask, by which an isolated fine pattern
10   can be produced.

While the invention has been described
with reference to the structures disclosed herein,
it is not confined to the details set forth and
this application is intended to cover such
15   modifications or changes as may come within the
purposes of the improvements or the scope of the
following claims.

CLAIMS

1.   An exposure mask for exposing an image
forming layer provided on a substrate, by use of
5   near field light leaking from adjoining openings
formed in a light blocking member, characterized
in that:

the light blocking film has an opening
interval that is determined so that an electric
10   field distribution at the image forming layer side
of the opening to be defined as exposure light is
projected on the light blocking member has a
correlation with an eccentric model of electric
field distribution as determined by a linewidth
15   and a height of a pattern to be produced.

2.   An exposure mask for exposing an image
forming layer provided on a substrate, by use of
near field light leaking from adjoining openings
20   formed in a light blocking member, characterized
in that:

a relation $K \geq (W+2T)$ is satisfied where
T is the height of a pattern to be produced by use
of the image forming layer, W is the linewidth of
25   the pattern, and K is the width of the light
blocking member being present between adjacent
openings.

　　　　3.　　An exposure mask for exposing an image
forming layer provided on a substrate, by use of
near field light leaking from adjoining openings
5　formed in a light blocking member, characterized
in that:
　　　　　　a relation $D \leq (P-W-2T)$ is satisfied
where T is the height of a pattern to be produced
by use of the image forming layer, W is the
10　linewidth of the pattern, P is the pitch of the
pattern, and D is the width of the opening.

　　　　4.　　An exposure mask for exposing an image
forming layer provided on a substrate, by use of
15　near field light leaking from adjoining openings
formed in a light blocking member, characterized
in that:
　　　　　　a relation $D=\{P-W-2T(1+\alpha)\}$ is
substantially satisfied where T is the height of a
20　pattern to be produced by use of the image forming
layer, W is the linewidth of the pattern, P is the
pitch of the pattern, and D is the width of the
opening while taking into account a process margin
α after the exposure.

25

　　　　5.　　An exposure mask according to Claim 3
or 4, wherein the value of the pitch is made not

grater than the wavelength of a surface plasmon
polariton wave to be produced on the basis of the
light blocking member.

5   6.   An exposure mask according to any one
of Claims 1 - 5, wherein the openings of the mask
have a two-dimensional shape or they are arranged
two-dimensionally, with respect to a direction
along the surface of the light blocking member
10   where the openings are formed.

           7.   A method of designing an exposure mask
for exposing an image forming layer provided on a
substrate, by use of near field light leaking from
15   adjoining openings formed in a light blocking
member, characterized in that:
           an opening interval of the light
blocking film is determined on the basis of a
linewidth and a height of a pattern to be produced
20   by use of the image forming layer.

           8.   A method of manufacturing an exposure
mask for exposing an image forming layer provided
on a substrate, by use of near field light leaking
25   from adjoining openings formed in a light blocking
member, characterized in that:
           an opening interval of the light

blocking film is determined on the basis of a
linewidth and a height of a pattern to be produced
by use of the image forming layer, and that, the
light blocking member is subsequently processed so
5   as to obtain the thus determined opening interval.

     9.   An exposure method for exposing an
image forming layer provided on a substrate, by
use of an exposure mask having a light blocking
10   member with an opening and on the basis of near
field light leaking from the opening,
characterized by:
          a step of preparing an exposure mask as
recited in any one of Claims 1 - 6;
15   a step of approximating the near-field
exposure mask and the image forming layer to each
other, up to a distance not greater than a near
field region; and
          an exposure step for irradiating the
20   image forming layer with exposure light through
the exposure mask.

     10. An exposure method according to Claim 9,
wherein, where P is the pitch of a pattern to be
25   produced by use of the image forming layer, D is
the width of the opening, W' is the linewidth, and
T' is the pattern height, through adjustment of an

exposure amount in the exposure step and of
another condition or conditions, an exposure is
carried out to satisfy a relation $(W'+2T') \leq (P-D)$.

5   11.   A pattern forming method including an
exposure step for exposing an image forming layer
on the basis of near field light and by use of a
near-field exposure mask having a light blocking
member with openings having a pitch P and an
10   opening width D, and a developing step for
developing the exposed image forming layer,
characterized in that:
          through adjustment of an exposure
amount in the exposure step and a developing
15   condition in the developing step, a pattern having
a linewidth W and a height T satisfying a relation
$(W+2T) \leq (P-D)$ is produced.

         12. A method according to Claim 11, wherein,
20   where a minimum value of the height T of the
pattern is determined as T'' due to process after
the pattern formation, a pattern having a
linewidth W that satisfies a relation $W \leq (P-D-2T'')$
is produced.

25

         13.   A device manufacturing method
characterized by including an exposure step for

exposing a process object by use of an exposure

method as recited in Claim 9, and a developing

step for developing the exposed process object,

wherein, after these steps, a predetermined

5   process is conducted to the process object,

whereby a device is manufactured.

14.   An exposure apparatus including light

irradiating means and an exposure mask, for

10   exposing a process object provided on a substrate,

by use of near field light leaking from a

plurality of openings formed in a light blocking

member of the mask, characterized in that:

as the exposure mask, said exposure

15   apparatus comprises an exposure mask as recited in

any one of Claims 1 - 6.

FIG. 1

FIG.2

FIG.3

FIG.4

OPENING
WIDTH "D"

PITCH "P"

FIG.5

FIG.6
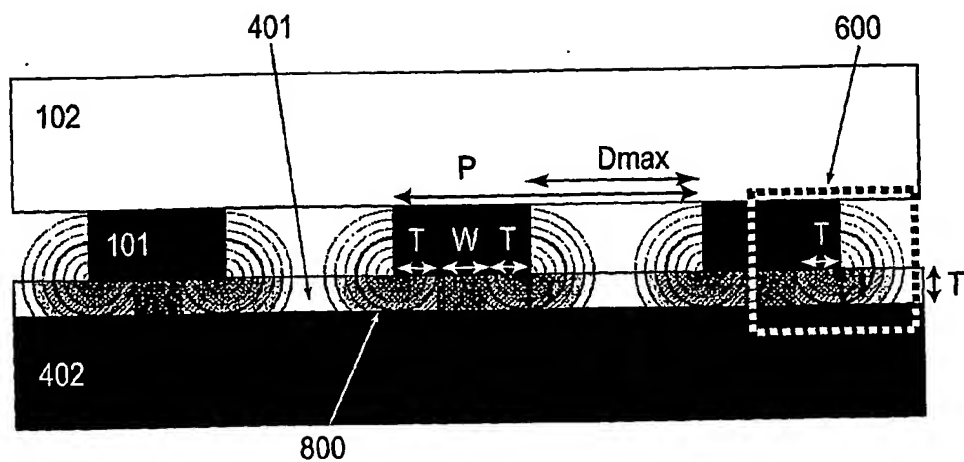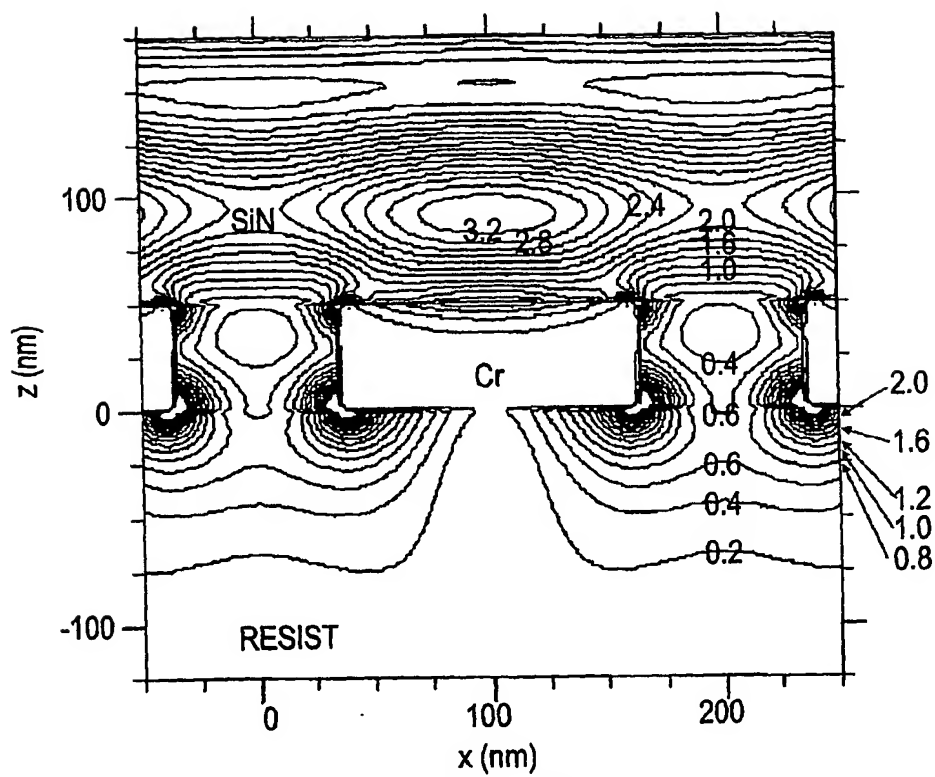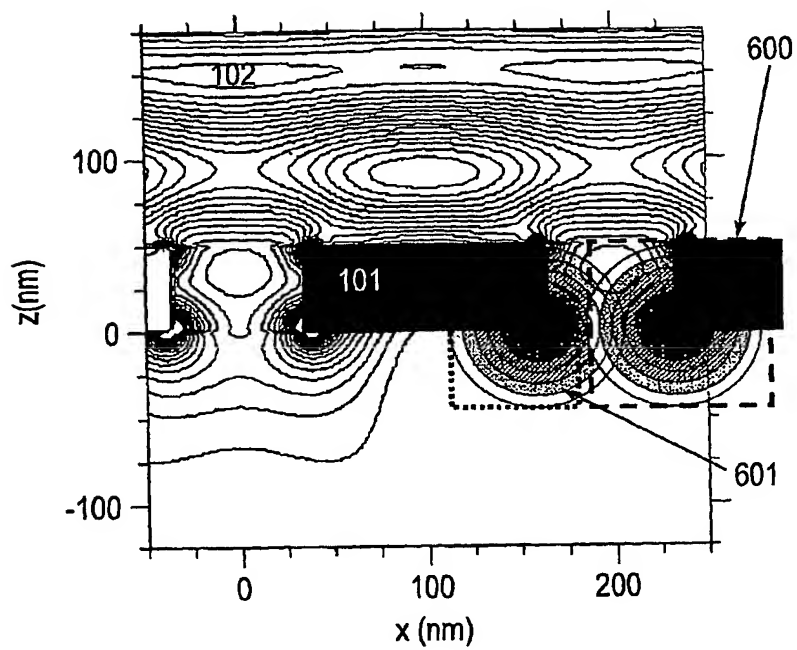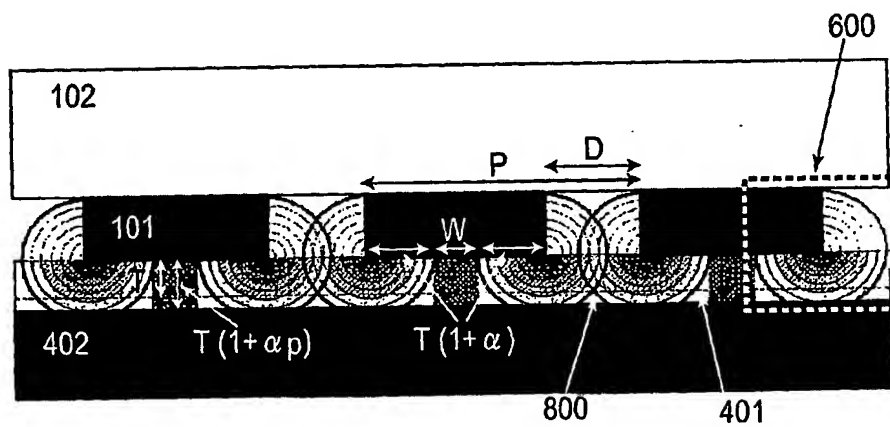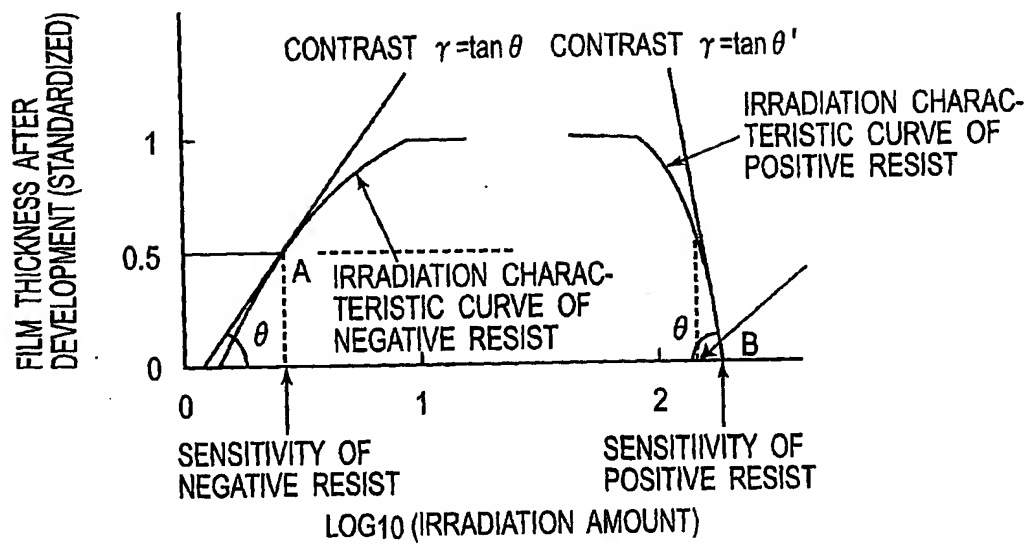
FIG.7
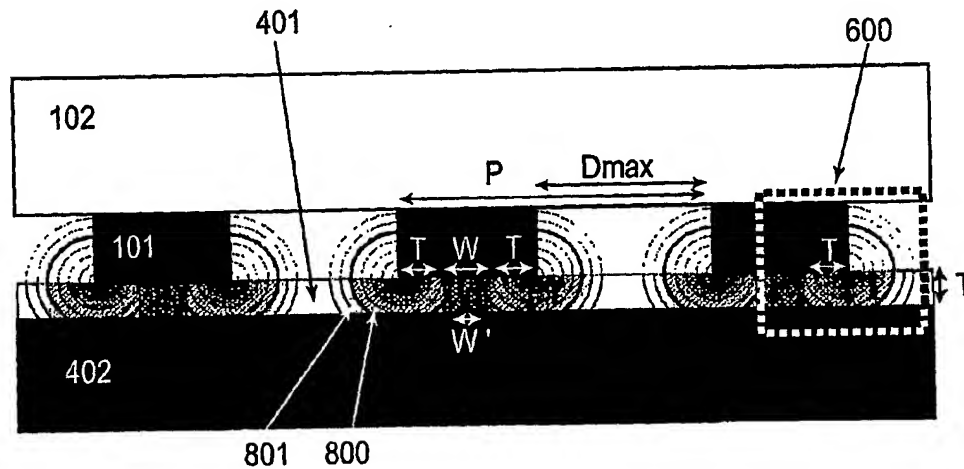
FIG.8
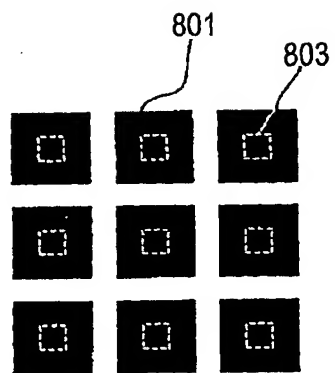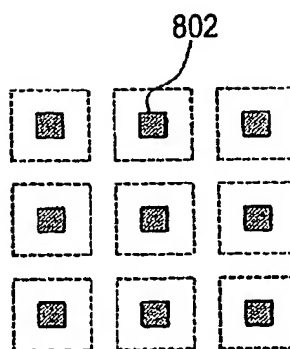
FIG.9A

FIG.9A'
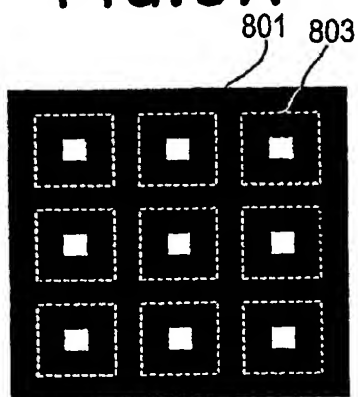
FIG.9B
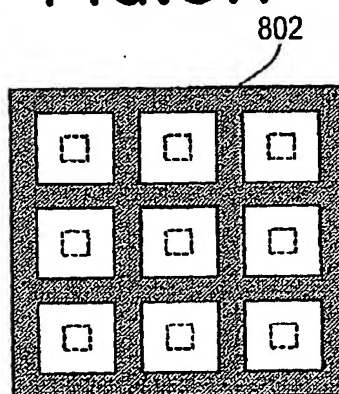
FIG.9B'
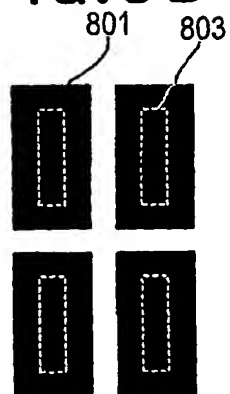
FIG.9C
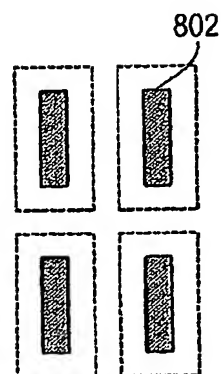
FIG.9C'
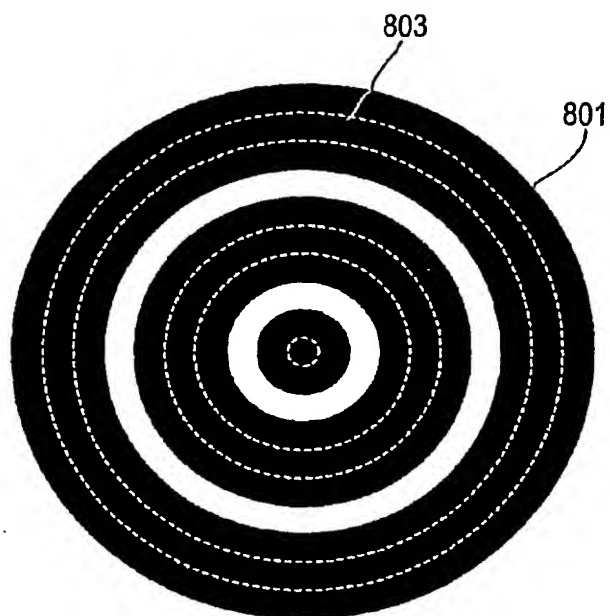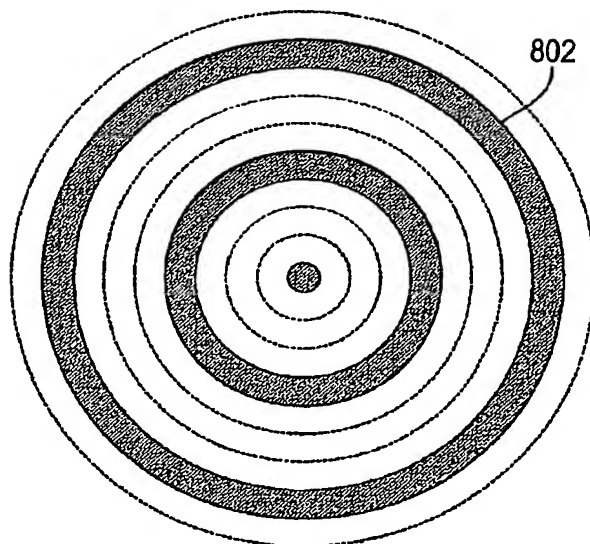
FIG. 10A

FIG. 10B
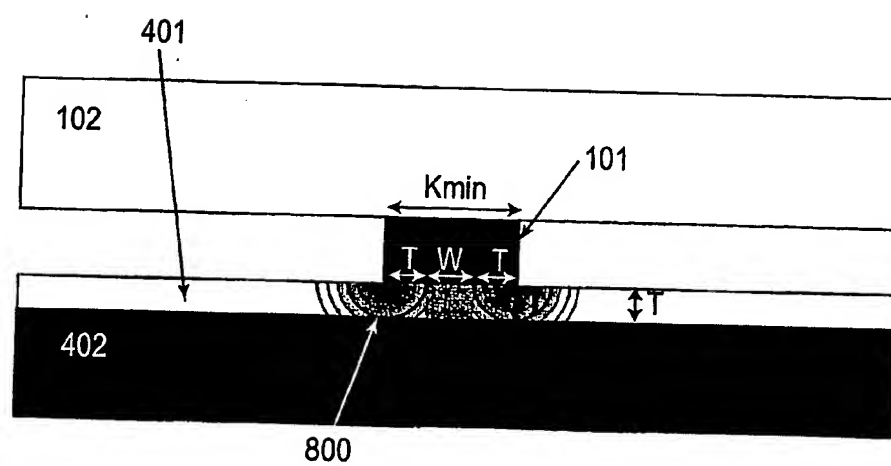
FIG.11

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7   G03F1/14   G03F7/20

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7   G03F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	ALKAISI M M ET AL: "NANOLITHOGRAPHY IN THE EVANESCENT NEAR FIELD" ADVANCED MATERIALS, VCH VERLAGSGESELLSCHAFT, WEINHEIM, DE, vol. 13, no. 12/13, 4 July 2001 (2001-07-04), pages 877-887, XP001130146 ISSN: 0935-9648 the whole document -/--	1-14

[X] Further documents are listed in the continuation of box C.   [X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search

9 September 2004

Date of mailing of the international search report

27/09/2004

Name and mailing address of the ISA
European Patent Office, P.B. 5818 Patentlaan 2
NL – 2280 HV Rijswijk
Tel. (+31–70) 340–2040, Tx. 31 651 epo nl,
Fax: (+31–70) 340–3016

Authorized officer

Hagner, T

Form PCT/ISA/210 (second sheet) (January 2004)

3

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	MCNAB S J ET AL: "Analytic study of gratings patterned by evanescent near field optical lithography" JOURNAL OF VACUUM SCIENCE & TECHNOLOGY B: MICROELECTRONICS PROCESSING AND PHENOMENA, AMERICAN VACUUM SOCIETY, NEW YORK, NY, US, vol. 18, no. 6, November 2000 (2000-11), pages 2900-2904, XP012008487 ISSN: 0734-211X the whole document	1-14
P,X	XIANGANG LUO ET AL: "Surface plasmon resonant interference nanolithography technique" APPLIED PHYSICS LETTERS AIP USA, vol. 84, no. 23, 22 April 2004 (2004-04-22), pages 4780-4782, XP002294549 ISSN: 0003-6951 the whole document	1-14
X	US 6 171 730 B1 (IKEDA TSUTOMU ET AL) 9 January 2001 (2001-01-09) cited in the application abstract; figures 1-9 column 1, line 55 - column 3, line 40	1,6-9, 13,14
X	WO 03/001869 A (CALIFORNIA INST OF TECHN) 9 January 2003 (2003-01-09) abstract; figures 1-4 page 1 - page 4 page 6 - page 16	1,6-9, 13,14
X	US 2001/046719 A1 (KURODA RYO ET AL) 29 November 2001 (2001-11-29) the whole document	1,6-9, 13,14

3

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
US 6171730	B1	09-01-2001	JP	11145051 A	28-05-1999
			JP	11184094 A	09-07-1999
WO 03001869	A	09-01-2003	WO	03001869 A2	09-01-2003
			US	2003129545 A1	10-07-2003
US 2001046719	A1	29-11-2001	JP	2001308002 A	02-11-2001
			US	2004023161 A1	05-02-2004